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**Diagnosis threat and injury beliefs after mild traumatic
brain injury**

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Review

Diagnosis threat and injury beliefs after mild traumatic brain injury

Background: Diagnosis threat is a psychosocial factor proposed to contribute to poor cognitive outcomes following mild traumatic brain injury (mTBI). The current research explored diagnosis threat impact on objective and subjective cognitive performance in a ‘high risk’ population of athletes. Two possible moderators of diagnosis threat – injury beliefs and suggestibility – were also investigated.

Method: Seventy-six participants with a history of mTBI were recruited through sports clubs and randomised to a months threat group (instructions drew attention to mTBI history) or a control group (no mention of mTBI). They completed a battery of neuropsychological tests and questionnaires regarding day-to-day cognitive abilities. Measures of depression, anxiety, illness beliefs and suggestibility were also collected.

Results: No significant group differences were found on any neuropsychological tasks, nor on self-report of cognitive difficulties. Illness beliefs were not found to play a moderating role in general, although the majority of the study sample did not report negative mTBI beliefs and expectations: concern about the consequences of injury was associated with weaker performance on one test, WAIS-III Digit Span performance. Suggestibility was also found to have a significant impact on this test.

Conclusions: Diagnosis threat did not appear to have a marked impact on objective or subjective cognitive performance after mTBI in athletes. Differing injury beliefs between the study’s athlete population and the general population is a possible explanation for different findings in the area. This and other sources of potential variation in the impact of diagnosis threat are discussed.

Keywords: Concussion; Stereotype threat; Attention; Memory; Illness perceptions; Suggestibility

Introduction

Mild traumatic brain injuries (mTBI) are common; in the UK, around 1 million people present at hospital following a head injury and of these, 90% are mild (Kay & Teasdale, 2001).

Cognitive deficits are often reported following mTBI; whilst for the majority such difficulties, along with emotional and physical symptoms, tend to resolve by three months post-injury (Carroll et al., 2004), a number of people experience persistent symptoms beyond this expected time frame (Dikmen, Machamer, Fann, & Temkin, 2010; Iverson, 2005). This phenomena is often referred to as post-concussion syndrome (PCS; Ryan & Warden, 2003) and can have a long term negative impact on quality of life, social and work functioning (Ahman, Saveman, Styrke, Bjornstig, & Stalnacke, 2013; Emanuelson, Andersson Holmkvist, Bjorklund, & Stalhammar, 2003; Kendall, 1996; King N. S. & Kirwilliam, 2011).

The current prevailing view of persistent cognitive (and other) difficulties following mTBI is typically framed in terms of biopsychosocial / diathesis-stressor models (Lishman, 1988; Silverberg & Iverson, 2011; Wood, 2004): biological factors are involved in the initial aetiology of mTBI, with their role lessening over time and other factors having greater responsibility for symptom maintenance (King, 2003; Meares S. et al., 2011; Ponsford et al., 2012). As a result, research has expanded from investigating links between physiological brain changes and neuropsychological test outcome (e.g. Gale, Johnson, Bigler, & Blatter, 1995) to looking at the role of premorbid factors such as gender and psychiatric history (Ponsford et al., 2000) and psychological factors, such as depression and anxiety (Clarke, Genat, & Anderson, 2012; Meares S. et al., 2006) and expectations (Belanger, Barwick, Kip, Kretzmer, & Vanderploeg, 2013; Gunstad & Suhr, 2001; Mittenberg, DiGiulio, Perrin, & Bass, 1992), on neuropsychological outcomes.

A key situational phenomenon that may play a role in persistent PCS symptoms is stereotype threat. Stereotype threat occurs via cues in the environment that activate

negative stereotypes about one’s social identity and lower expectations for individual performance, which in turn negatively impact behaviour (Steele C. M., 1997). Neither a history of stigmatisation nor internalised feelings of inferiority are necessary for individuals to succumb to stereotype threat; it can arise as a result of situational pressures alone (Aronson et al., 1999). Stereotype threat has been found to have a detrimental influence on a wide range of behaviours in varying populations, including cognitive testing in African-American students (Steele & Aronson, 1995) and those from a low socioeconomic background (Croizet & Claire, 1998); mathematical skills in women (Doyle & Voyer, 2016); and memory in older adults (Levy, 1996).

Despite the large body of work demonstrating the stereotype threat effect, there remains uncertainty around the underlying mechanisms involved. One proposed moderator is that heightened anxiety around confirming the negative stereotype interferes with task performance (Steele & Aronson, 1995), either owing to task-irrelevant anxious thoughts reducing the working memory capacity available to allocate to the task at hand or ‘evaluation apprehension’ leading to greater cautiousness (e.g. reducing the number of task items attempted) (Beilock, Rydell, & McConnell, 2007; Schmader, Johns, & Forbes, 2008). Reduced motivation and effort (Hess, Auman, Colcombe, & Rahhal, 2003; Stone, 2002) have also been investigated as possible moderators of stereotype threat (i.e. self-handicapping to provide an a priori explanation for failure). Kit, Tuokko, and Mateer (2008) suggest the lack of clarity around contributing mechanisms reflects the complexity of the stereotype threat effect, with multiple variables having different contributions across different settings and groups.

Diagnosis threat – the term for stereotype threat when in reference to neurological populations – was initially investigated by Suhr & Gunstad (2002, 2005). They found

undergraduates that had their attention drawn to a prior mTBI performed worse on cognitive tests, although more recent studies have failed to replicate the size or range of cognitive decrements reported by the original research (Blaine, Sullivan, & Edmed, 2013; Kinkela, 2009; Ozen & Fernandes, 2011). Ozen and Fernandes (2011) suggest subjective reports of everyday functioning may be more susceptible to diagnosis threat than objective performance on neuropsychological tests.

Little research has been done into moderating variables that may explain differences in study outcomes. In an extension of their original study, Suhr and Gunstad (2005) found neither anxiety nor effort explained group differences between arms. Group identification (Pavawalla, Salazar, Cimino, Belanger, and Vanderploeg (2013) and self-efficacy (Kit, Mateer, Tuokko, & Spencer-Rodgers, 2014; Trontel, 2013) have also been posited as possible moderators.

A possible moderator for differences in the diagnosis threat literature is illness beliefs. The term comprises individual's views on the identity, consequences, timeline, controllability and causal attributions of their health condition (Leventhal Howard, Leventhal, & Contrada, 1998; Leventhal H., Meyer, & Nerenz, 1980). Within mTBI, greater endorsement of negative beliefs around the identity, consequences, timeline, controllability and causal attributions of the injury have been found to be related to greater symptom report (Var & Rajeswaran, 2012) and can be predictive of PCS (Hou et al., 2012; Snell, Hay-Smith, Surgenor, & Siegert, 2013; Snell, Siegert, Hay-Smith, & Surgenor, 2011; Snell D. L., Surgenor, Hay-Smith, Williman, & Siegert, 2015; Whittaker, Kemp, & House, 2007).

In a recent literature review, Block, West and Goldin (2016) presented a conceptual model highlighting the antecedents, beliefs and consequences of misconceptions and

misattributions about traumatic brain injury. Factors impacting variability of individual's beliefs included where people received information from, group beliefs, attribution of behaviours to TBI and survivor expectations (i.e. "expectation as aetiology"; Mittenberg et al., 1992). The variability caused by these factors are reflected in the wider literature: Although there is evidence that the general population can hold negative expectations around outcome for even relatively mild TBIs (Mulhern & McMillan, 2006; Sullivan & Edmed, 2012), it is also clear that this is not pervasive and may be primed by the experimental context (Mackenzie & McMillan, 2005; Mulhern & McMillan, 2006). Expectations may also vary according to the group of individuals being studied. For example, athletes often do not perceive concussion as a serious injury and expect few long-term consequences (Delaney, Lamfookon, Bloom, Al-Kashmiri, & Correa, 2015; McCrea, Hammeke, Olsen, Leo, & Guskiewicz, 2004). Previous research has not investigated injury belief biases and variation in relation to the impact of diagnosis threat.

The nocebo effect (Bootzin & Bailey, 2005) of beliefs and expectations described above is thought to be moderated by individual differences in suggestibility, defined as the tendency to accept and act on external influences (Delis & Wetter, 2007; Spiegel, 1997). This construct seems well placed as a source of potential individual difference that might explain the heterogeneity of diagnosis threat study results. However, the variable has not received investigation in mTBI literature, despite being highlighted as a possible avenue for future research (Kit et al., 2014).

The current study aimed to replicate previous findings of diagnosis threat impact on objective and subjective reporting of cognitive difficulties in a specific population at higher risk for mTBI - amateur athletes engaged in contact sports (for this study, boxing and rugby) (Gravel

et al., 2013; Langlois, Rutland-Brown, & Wald, 2006). This contrasts with the majority of diagnosis threat studies which have been conducted in undergraduate university samples.

A second aim of the study was to investigate pre-existing injury beliefs and suggestibility as potential moderators of diagnosis threat. To our knowledge, no study has yet investigated these factors, despite them being core to the stereotype threat experimental paradigm. It was hypothesised that individuals holding more negative beliefs that about their injury (i.e. that it has serious negative consequences) would be subject to greater diagnosis threat, performing worse on neuropsychological measures and reporting a greater degree of subjective cognitive problems. Similarly, it was predicted that those in the experimental diagnosis threat arm scoring high on suggestibility would be more susceptible to diagnosis threat.

Method

Participants

A priori power analysis based on Suhr & Gunstad's (2002) results indicated that a sample size of 62 would be sufficient to detect a significant effect of diagnosis threat, with a power of .90 and an alpha of .05.

Participants were recruited via 16 London-based boxing clubs and 4 London-based rugby clubs. 76 individuals met study inclusion criteria for mTBI (defined as per the American Congress of Rehabilitation Medicine's definition (Kay et al., 1993), with individuals excluded if injuries were less than three months before, to ensure any differences in performance were not owing to actual concussive symptoms that can be present within the timeframe (Carroll et al., 2004). Individuals were also excluded if they were receiving ongoing investigations or treatment for these injuries, or if they were involved in any ongoing litigation

regarding them. Their demographic information is shown in *Table 1*. The study was approved by King's College London (KCL) College Research Ethics Committees' Psychiatry, Nursing & Midwifery Research Ethics Subcommittee (CREC).

[INSERT TABLE 1 HERE]

Measures

Injury-related and demographic information: Individuals who met criteria for inclusion were asked to provide injury-related (date and cause of injury, length of loss or alteration of consciousness, length of PTA, details of any treatment received at the time of injury), clinical (ongoing medical investigations or treatments, specialist appointments, involvement in litigation or medicolegal claims, level of alcohol intake, current medication) and demographic information.

Cognitive measures: The Wechsler Test of Adult Reading (WTAR; Holdnack, 2001) was administered to glean an estimate of Full Scale IQ. Subtests of the Wechsler Adult Intelligence Scale-III (WAIS-III; Wechsler, 1997) that tapped into domains found to be most susceptible to diagnosis threat (Suhr & Gunstad, 2005) were used; attention / working memory was assessed using the Digit Span, Letter Number Sequencing, and Mental Arithmetic subtests, while psychomotor speed was assessed using the Digit-Symbol Coding subtest.

Self-report questionnaires: The Attention-related Cognitive Error Scale and Memory Failures Scale (ARCES & MFS; Carriere, Cheyne, & Smilek, 2008) were used to measure subjective ratings of day-to-day cognitive performance. Both scales are contain twelve questions rated on a 5-point Likert scale ranging from 'Never' to 'Very Often'. Higher scores reflect more frequent attention / memory lapses.

Participant beliefs about their mTBI was assessed at the screening stage using the Brief Illness Perception Questionnaire (B-IPQ; Broadbent, Petrie, Main, & Weinman, 2006), which comprises eight items (identity; timeline; personal control; treatment control; symptoms; concern; understanding; emotional impact) rated using a 0-10 Likert scale. A ninth open-ended response item was omitted in the current study. Higher scores indicated stronger negative beliefs about mTBI. The Gudjonsson Compliance Scale (GuCS; Gudjonsson, 1989), a 20-item true / false questionnaire, was used as a measure of suggestibility with higher scores indicating higher suggestibility.

Participants also completed the Beck Depression Inventory-II (BDI-II; Beck, Steer, & Brown, 1996), the trait subscale of the State-Trait Anxiety Inventory (STAI; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 2010) and the neuroticism subscale of the revised Eysenck Personality Questionnaire – Short form (EPQ; Eysenck, Eysenck, & Barrett, 1985). The EPQ was not administered for data synthesis, but rather as a distractor item to reduce the chance of participants guessing the experimental hypotheses.

Procedure

Potential participants were screened at their respective sports clubs via a confidential general health screen. At screening, participants received an information and consent to contact sheet informing them that they were being invited to participate in a study entitled “Thinking skills, personality and self-beliefs in amateur sportsmen and sportswomen”. Questions probing head injury status and exclusion criteria were couched within questions about general health and injury history in order to mask the study’s focus on mTBI. Participants who reported a history of mTBI at least three months before were contacted a week later and invited to take part in the study. Overall, 302 individuals were screened, and 98 people (32%) met criteria for having sustained an mTBI in the past and of those 76 (78%) agreed to take part in the study when contacted. Participant flow can be seen in *Figure 1*.

[INSERT FIGURE 1 HERE]

Permuted block randomisation by strata (type of sports club) was used to assign participants to experimental or control conditions, with block size randomly varied to avoid predictability. The randomisation procedure was done by an individual outside of the research team. Participants completed the study at university buildings or, where available, in a quiet room at sports club. After written consent was obtained each participant was given an envelope with instructions adapted from those used by Suhr and Gunstad (2002) inside (see *Appendix 1*). Participants were asked to read the contents and return the instructions to the envelope without notifying the researcher, ensuring the researcher remained blind to group allocation.

Participants then completed the neuropsychological tasks and questionnaires in the following order: W-TAR, Digit-Span, Arithmetic, Letter-Number Sequencing and Digit-Symbol Coding, ARCES, MFS, BDI, STAI-T, EPQ-N and GuCS. The B-IPQ was administered at the screening stage in order to prevent inadvertent activation of illness beliefs impacting test performance or B-IPQ responses being influenced by perceived performance.

At the end of the study participants were debriefed. It was explained that they had been selected on the basis of having sustained mTBI at any time in the past and the main hypotheses of the study was revealed. It was clarified that any information given within test instructions regarding the effect of head injury on thinking ability is rarely found with individuals suffering from an mTBI and that many individuals with a history of head injury do not experience thinking difficulties at all. Participants were remunerated £10 at the end of the study.

Results

Preliminary analysis

All data met assumptions of normality, with the exception of the BDI (which displayed floor effects) and the WTAR-predicted FSIQ (which showed negative skew). The latter was transformed by squaring the data, which corrected the non-normal distribution, and the updated dataset was used for the statistical analysis.

Preliminary analyses were undertaken to determine whether study randomisation had resulted in similar groups on demographic and other baseline characteristics. There were no significant differences between experimental and control participants on demographic, clinical or injury-related data collected, nor on testing location (See *Table 1*).

Main analysis

Based on past studies, it was predicted that participants in the diagnosis threat arm would show impaired neuropsychological test performance compared to those in the control arm. A secondary hypothesis was that people subject to the diagnosis threat condition would self-report more failures of attention and memory compared to those in the neutral condition. Independent sample T-tests were used to compare groups on performance on neuropsychological tests and self-report more failures of attention and memory. No significant effects were found for performance on any neuropsychological test measures or for responses on the ARCES or MFS (See *Table 2*).

[INSERT TABLE 2 HERE]

Analysis of moderators

It was hypothesised that there would be an interaction between illness beliefs and diagnosis threat, whereby individuals holding beliefs that their symptoms have serious negative

consequences (as measured by individual B-IPQ questions) and who were subject to diagnosis threat would perform worse on neuropsychological measures and report a greater degree of subjective cognitive problems. This hypothesis was tested with 2 x 2 ANCOVAs, with group (diagnosis threat / neutral) and B-IPQ question scores (range 0-10) as between participant factors. Contrary to expectations, only one Group x Belief interaction was noted: a significant Group x Concern interaction emerged on Digit Span ($F(1, 72) = 4.09, p = .047$), with those rating themselves as concerned about their injury experiencing a greater performance decrement as a result of diagnosis threat instructions. No significant interactions were found between diagnosis threat group and any other B-IPQ construct (i.e. identity; timeline; personal control; treatment control; symptoms; understanding; emotional impact) on responses on WAIS-III subtests, ARCES or MFS.

Finally, the hypothesis that individuals scoring higher on the GuCS and who were in the diagnosis threat condition would perform worse on neuropsychological measures and report a greater degree of subjective cognitive problems was investigated using a 2 x 2 ANCOVA. Threat condition (diagnosis threat / neutral) and suggestibility (range 0-20) were between participant factors. A significant Group x Suggestibility interaction emerged on the Digit Span, with those scoring high in suggestibility experiencing a greater performance decrement as a result of diagnosis threat instructions ($F(1, 72) = 4.547, p = .036$). Each point increase on the GuCS was associated with a .36 decrease on Digit Span performance ($\beta = -.36, t(76) = -2.132, p = .036, 95\% \text{ CI } (-.694 - -.023)$). No Group x Suggestibility interaction was noted for Arithmetic ($F(1, 72) = .167, p = .684$), Letter-Number Sequencing ($F(1, 72) = .496, p = .483$) or Coding scores ($F(1, 72) = 2.098, p = .152$). Additionally, no significant interaction was found for responses on the ARCES ($F(1, 72) = .586, p = .446$) or the MFS ($F(1, 72) = .130, p = .719$). None of the assumptions of the ANCOVA test were violated.

Discussion

This experimental study used a randomised design to investigate whether alerting individuals to their history of mTBI to activate negative expectations (i.e. diagnosis threat) was associated with lower neuropsychological test performance and greater subjective reporting of cognitive difficulties.

Contrary to the study's hypotheses, results showed no difference on performance between participants in the diagnosis threat arm and those in the control arm on any of the neuropsychological tests of working memory / attention or processing speed, nor on self-report of day-to-day cognitive lapses. The data showed a trend in the opposite direction than hypothesised, with the diagnosis threat group performing marginally (and non-significantly) better on two measures (WAIS-III Letter-Number Sequencing & WAIS-III Coding).

One possible explanation for the null finding is that participants may not have identified with the 'mTBI' stereotype strongly enough for it to elicit a diagnosis threat response. Group identification has been found to be a moderator for both diagnosis threat (Pavawalla et al., 2013) and stereotype threat in general (Steele, Spencer, & Aronson, 2002). Given reported injuries typically took place a long time ago (mean=56 months; SD=69.14) and were at the mild end of mTBI - mean LOC was 1.7 minutes (SD=4.75) while mean PTA was 2.8 minutes (SD=5.7) - participants may not have seen the 'mTBI' stereotype as personally relevant. In addition, the academic nature of the neuropsychological tasks and testing environment may have led to the activation of more salient 'student' or 'professional' stereotypes in some, which would include positive beliefs about cognitive ability.

The secondary hypothesis that injury beliefs would play a moderating role in whether individuals succumbed to diagnosis threat was only partially supported, with participants

reporting greater concern about their mTBI on the B-IPQ performing significantly worse on one neuropsychological task when exposed to diagnosis threat. However, data collected for the current study comprised almost exclusively neutral or positive beliefs / expectations around the impact of mTBI, making it difficult to draw clear conclusions. Given that much of the theory behind stereotype threat highlights the presence of negative and stigmatising stereotypes, it may be that illness beliefs only have a deleterious effect when explicitly negative. The skew in reporting of injury beliefs may be a product of the specific population recruited (i.e. amateur athletes), who may hold more benign views on mTBI and its prognosis compared to the general population.

Study population characteristics may explain the lack of reported negative expectations around mTBI. Few participants actively sought treatment for their mTBI, which already suggests a low level of concern regarding the impact of the injury. This is in contrast to other studies investigating mTBI injury beliefs, which have recruited participants through A&E or concussion clinics (Hou et al., 2012; Snell et al., 2011; Whittaker et al., 2007). In addition, the majority of participants (85.5%) sustained their injury whilst playing sport, which may be perceived as a less negative mechanism of injury compared with, for example, a road traffic accident (Blaine et al., 2013).

The study recruited from a 'high risk' population of amateur athletes who, regardless of how they obtained their own injury, may have difference expectations regarding mTBI recovery compared to the general population. Athletes have been found to expect fewer symptoms than non-athletes or depressed individuals. Applying Block et al's (2016) TBI misconceptions/misattributions model to the findings, a "cascade" effect - where participants passively accept group beliefs (in this case benign beliefs held by other club members) as their own when they lack information – may have led to pre-existing expectations for speedy

recovery. Such expectations may also come from what Block et al (2016) refer to as attribution theory, for example participants' own concussion experience contrasting with negative stereotypes (Weber & Edwards, 2010) or witnessing others' positive mTBI recovery (Gunstad & Suhr, 2001).

The 'culture of concussion' has been an area of interest in sports research in recent years (Adler & Herring, 2011; Murray, Murray, & Robson, 2015), with studies looking into reasons why athletes often do not report mTBIs sustained during play (McCrea et al., 2004). Numerous beliefs have been found to have an impact, including beliefs related to perceived severity, desire to continue playing, importance of the match, ostracisation from teammates and disappointment from coaches (Chrisman, Quitquit, & Rivara, 2013; Delaney et al., 2015; McCrea et al., 2004; Register-Mihalik et al., 2013). Although researched in the context of under-reporting of mTBI during games, such beliefs around mTBI during play being something of an 'occupational hazard' may inoculate athletes from persistent PCS to a degree. Studies point to possible significant variations in these beliefs between athletes: in two studies examining whether different terms for concussion were associated with different expectations regarding consequences and recovery, one (Weber & Edwards, 2010) found more negative expectations regarding "mTBI" versus "concussion" whilst another (Edmed & Sullivan, 2015) didn't. Sources of variation may include the degree of contact and risk of injury in the sport, gender, or level of play (i.e. amateur vs. professional).

Results partially supported the hypothesis that suggestibility would impact susceptibility to diagnosis threat. Highly suggestible participants in the diagnosis threat arm experienced a greater performance decrement on one of the four neuropsychological tasks (WAIS-III Digit Span). This is in line with the suggestion by Delis and Wetter (2007) that highly suggestible individuals may be especially prone to report higher levels of cognitive dysfunction,

particularly in contexts that reinforce their beliefs in those deficits. This potential novel finding bears replication, particularly as the effect was only found in one of the neuropsychological tasks. The impact on the WAIS-III Digit Span subtest may have been owing a primacy effect; the WAIS-III Digit Span was the first neuropsychological test to be administered, when threat instructions were still fresh and anxiety may have been higher. To date, only one study of diagnosis threat (Blaine et al, 2013) has counterbalanced test order to control for order effects, but this should be considered in future research. Additionally, although not investigated in the current research owing to previous non-significant findings in the diagnosis threat literature (Suhr & Gunstad, 2005), a measure of state anxiety may have provided information on the nature of the finding.

The current study had a number of limitations. Although efforts were made to recruit a more representative study population than those employed in past research (often an exclusively undergraduate population) and of an at-risk group, participants recruited were still fairly homogenous with regards to age and professional background. As noted above, participants' sporting background may have resulted in the study population's mTBI injury beliefs not being representative of the general population. In addition, participants were not asked about multiple concussions or current PCS symptoms, knowledge (and exclusion) of which may have helped clarify how and on whom the diagnosis threat effect occurs. However, given recruitment was from a healthy, non-treatment seeking population, we would not expect ongoing mTBI complications to be present and it was felt that an additional focus on head injury details at the screening stage may have alerted participants to the nature of the study. Inclusion of a post-experimental probe as to whether participants remembered diagnosis threat instruction could have provided insight as to whether diagnosis threat had been adequately activated in our study. Additionally, a suspicion probe (e.g. "Do you have any guesses about what the study is really about? We would be interested in hearing any ideas you might have") to check whether participants were aware of the true study

hypothesis would have been informative, particularly given increased media coverage of mTBI in professional sports in the latter half of the data collection period (e.g. Katwala, 2014; Crouch, 2015). Such steps have not routinely been taken in other diagnosis threat research.

How patients' perceptions affect cognitive symptoms following mTBI is still unclear (Whittaker et al, 2007) and requires further research using a sample where participants have more negative illness perceptions than in the current study. Comparison of injury beliefs between an athlete mTBI group with a non-athlete mTBI group would help to shed light on whether the current study's athlete population holds significantly different beliefs to the general population, and if this has a differential impact of diagnosis threat. An alternative experimental paradigm would be to compare uninjured athletes and non-athletes on their B-IPQ scores of a hypothetical mTBI, which could highlight whether injury beliefs do play a role in recovery and whether the good recovery found in the majority of sports-related mTBI are because of positive injury beliefs 'immunising' individuals from a diagnosis threat effect. The relationship between illness beliefs and diagnosis threat could also be further investigated by conducting a post-assessment B-IPQ, to see if diagnosis threat led to a change of participants' responses on the measure.

The current study made efforts to improve ecological validity through its recruitment of a novel population (e.g. mTBI sufferers who do not present at hospital) and inclusion criteria (e.g. including those with a mental health diagnosis). Future research should continue to take steps that will allow generalisation of research to real life settings, such as replicating findings in a community-based mTBI sample who may be more likely to be at risk of developing PCS. Additionally, looking at diagnosis threat in combination with other factors from the biopsychosocial model may help our conceptual understanding of PCS and provide

greater clinical utility. It may be that PCS is a result of multiple factors (e.g. anxiety, negative beliefs) having a cumulative effect on vulnerable individuals.

The results of the study are in line with other research finding limiting effects of diagnosis threat (Blaine et al., 2013; Kinkela, 2009; Ozen & Fernandes, 2011) and suggest a need to rethink its role in PCS. However, differences between the experimental and clinical environment should be taken into account before the potential impact of diagnosis threat is dismissed. For example, patients who are being assessed for genuine diagnostic purposes may be impacted by a range of different or additional social / contextual cues that may impact beliefs and expectations, for example adopting a 'patient' identity (Blaine et al., 2013). Although situational factors such as diagnosis threat may be hard to actively control, there is evidence that beliefs about injury outcome (Borg et al., 2004; Comper, Bisschop, Carnide, & Tricco, 2005; Mittenberg, Tremont, Zielinski, Fichera, & Rayls, 1996; Silverberg et al., 2013) and cognitive capabilities (Mikulincer, 1990) may be amenable to change. Interventions that specifically target unhelpful beliefs about memory and concentration abilities may be helpful (Potter & Brown, 2012).

Conclusion

The current study, when taken with inconsistent findings in previous research, suggests the impact of diagnosis threat on neuropsychological test performance and subjective reports may need to be reconsidered. Although the effect should not be dismissed completely, differences between experimental paradigms and clinical settings should be taken into account. In particular, there may be a number of sources of individual differences which may contribute to variations across studies, which may in turn reflect the variety of mechanisms whereby PCS may resolve in the majority of individuals but persist for a minority. This study provided partial support implicating concern about injury and suggestibility as playing moderating roles in the strength of diagnosis threat. However, the wider negative findings for diagnosis threat on both objective and subjective cognitive performance highlights the

possibility that mTBI injury beliefs in athletes differ substantially from those in the general population, and leaves the question of whether these differences reduce the risk of persistent PCS in sportsmen and sportswomen.

Injury beliefs were not found to impact the strength of diagnosis threat, although the lack of overtly negative expectations in the study population (i.e. athletes) make it hard to draw firm conclusions. The research opens up avenues for future research into whether mTBI injury beliefs in athletes differ substantially from those in the general population and whether such beliefs are protective in any way from ongoing PCS complaints. In addition, there is evidence that suggestibility plays a moderating role in the strength of diagnosis threat. Further investigation into this variable is needed in order to see whether it may be a potential source of differences in outcome across the diagnosis threat literature.

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[INSERT APPENDIX 1 HERE]

Table 1. Demographic, clinical and injury-related characteristics of study participants

Table 2. Performance on neuropsychological tasks and questionnaires responses

Appendix 1. Study Instructions

For Peer Review

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Table 1.

Variable	Diagnosis Threat (N=39)	Control (N=37)	χ^2 (p)	T-value (p)
Age (years; M, SD)	28 (7.43)	27.89 (6.87)		.066 (.95)
Sex (Male; %)	82	86	.281 (.60)	
WTAR Predicted FSIQ (M, SD)	105.82 (8.90)	104.59 (8.83)		.601 (.550)
Occupation (Student; %)	23	35	4.68 (.096)	
1 st language (English; %)	92	89	.221 (.638)	
Sport (Boxers; %)	64	65		.005 (.945)
Testing location (University; %)	67	68	.007 (.93)	
Sports related injury (%)	85	86	3.283 (.656)	
Treatment sought (%)	15	24	.958 (.328)	
TSI (months; M, SD)	67.64 (81.97)	43.81 (50.66)		1.515 (.134)
LOC (%)	64	54	.436	

			(.509)	
LOC (minutes; <i>M</i> , <i>SD</i>)	1.06 (2.18)	2.48 (6.64)		
PTA (%)	36%	35%	.164 (.686)	
PTA (minutes; <i>M</i> , <i>SD</i>)	3.96 (7.52)	1.74 (3.27)		
B-IPQ (<i>M</i> , <i>SD</i>)	17.28 (11.75)	15.38 (12.19)		.694 (.490)
Mental health diagnosis (%)	5	5	.003 (.957)	
Neurological disorder (%)	5	5	.003 (.957)	
Depression (BDI; <i>M</i> , <i>SD</i> , % above cutoff*)	4.67 (5.28), 8	4.73 (3.46), 5		-.615 (.540)
Anxiety (STAI-T; <i>M</i> , <i>SD</i> , % above cutoff*)	36.21 (10.97), 18	35.41 (9.0), 19		.108 (.915)
Weekly alcohol consumption (units, <i>M</i> , <i>SD</i>)	10.13 (10.50)	10.32 (10.66)		-.081 (.936)
Suggestibility (GuCS; <i>M</i> , <i>SD</i>)	7.56 (3.53)	6.57 (3.69)		1.203 (.096)

Note: WTAR= Wechsler Test of Adult Reading; FSIQ=Full Scale Intelligence Quotient; TSI=Time

Since Injury; LOC=Loss of Consciousness; PTA=Post Traumatic Amnesia; B-IPQ=Brief Illness

Perceptions Questionnaire; BDI=Beck Depression Inventory; STAI-T=State Trait Anxiety Inventory – trait subscale; GuCS= Gudjonsson Compliance Scale

* BDI cut-off for depression >14; STAI-T cut-off for anxiety >45

Table 2.

Variable	Diagnosis	Control	Post hoc	
	Threat		differences	
	Mean (sd)	Mean (sd)	t	p
Neuropsychological tests				
WAIS-III Digit Span	11.59 (3.18)	11.81 (2.30)	-.346	.731
WAIS-III Arithmetic	12.26 (2.79)	11.84 (2.97)	.634	.528
WAIS-III Letter-Number Sequencing	12.77 (3.91)	11.51 (3.37)	1.496	.139
WAIS-III Coding	11.92 (3.01)	10.86 (2.67)	1.618	.110
Subjective cognitive difficulties report				
ARCES	29.90 (6.88)	30.89 (8.08)	-.579	.564
MFS	26.13 (5.88)	25.54 (5.87)	.436	.664

Note: WAIS-III= Wechsler Adult Intelligence Scale – 3rd Edition; ARCES= Attention-Related Cognitive Errors Scale; MFS=Memory Failures Scale

Appendix 1.

Diagnosis threat condition	Control condition
<p>You have been invited to participate in this study because of your response to one of the questionnaires included in the initial general health screening. Your response indicated a history of head injury / concussion. A growing number of neuropsychological / thinking skills studies find that many individuals with head injuries / concussions show cognitive deficits on neuropsychological / thinking skills tests. Deficits in areas such as attention, memory and speed of information processing are common, though other deficits sometimes emerge. This study examines the role that head injury may play in these cognitive areas to better understand the nature of the disorder.</p> <p>The experimenter will now ask you to complete a brief collection of common thinking skills / neuropsychological tests. These tests will assess skills such as attention, memory, speed of information processing, etc. Some of the tests are easy, some are more difficult. Please give your best effort. You will then be asked to complete some questionnaires asking about your thinking skills, personality and mood. Questions about individual tasks will be answered following the testing.</p>	<p>The experimenter will now ask you to complete a brief collection of common thinking skills / neuropsychological tests. These tests will assess skills such as attention, memory, speed of information processing, etc. Some of the tests are easy, some are more difficult. Please give your best effort. You will then be asked to complete some questionnaires asking about your thinking skills, personality and mood. Questions about individual tasks will be answered following the testing.</p>

Figure 1. CONSORT flow diagram showing progression of participant through study

Figure 1.

